Species Report of *Panicum fauriei* var. *carteri* (Carter's panicgrass)
Version 1.0

Panicum fauriei var. *carteri* at Mokoliʻi island of Oʻahu. Photo credit: Forest & Kim Starr

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EXECUTIVE SUMMARY

This Species Report summarizes the biology and current status of *Panicum fauriei* var. *carteri*. It is a biological report that provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

We assessed viability of the species using the three conservation biology principles of resiliency, representation, and redundancy. Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. Representation is having more than one population of a species occupying the full range of habitat types used by the species and securing all of the genetic structure within the species.

Panicum fauriei var. *carteri* (Hosaka) Davidse, or Carter's panicgrass, is short-lived annual low-tufted grass in the Poaceae (grass) family. A revision of the Hawaiian species of *Panicum* merged eleven previously described species into the *Panicum fauriei* complex based on the uniform stem, leaf, and inflorescence morphology (Davidse 1990). This complex consists of three varieties (*P. fauriei* var. *carteri*, *P. fauriei* var. *fauriei*, and *P. fauriei* var. *latius*). These species occur in the coastal habitat in rock land, rough mountainous land, or Ko‘ele-Rocky complex soils (USFWS 2020, unpublished data). *P. fauriei* var. *carteri* populations receive fewer than 47 inches (in) (1,200 millimeters [mm]) of average annual rainfall, direct sunlight, and sea spray.

The main threats to *Panicum fauriei* var. *carteri* are nonnative plants, introduced ungulates, rodents, nonnative insects, fire or other catastrophic events, direct human disturbance, low number of individuals, lack of regeneration, climate change, and inadequate regulatory mechanisms. Conservation actions that are helping to control these threats include ungulate fencing, controlling nonnative plants, collecting seeds, reintroduce individuals, monitoring, and regulatory actions. Plants are found in living collections for this species.

Resiliency of *Panicum fauriei* var. *carteri* is based on the metrics of population size (number of individuals), population growth rate and trends (over time), and population structure (age or size class distribution: presence of seedlings, immature, and mature individuals). Redundancy of *P. fauriei* var. *carteri* is evaluated on the metrics of the number of populations, their resiliency, and the distribution and proximity of populations across its range. Representation is measured on the number of populations in a unique habitat type and the number of populations possessing unique traits.

Given that there are five known wild population units containing 376 wild individuals and 40 translocated individuals in another population unit, on the population level *Panicum fauriei* var. *carteri* has <u>very low to low</u> overall resiliency. On the species level, it has <u>low</u> redundancy and <u>very low to low</u> representation. Therefore, the current viability is <u>very low to low</u>. We would expect *P. fauriei* var. *carteri* to be particularly vulnerable to all the threats listed above. Some redundancy and representation is maintained in *ex situ* rare plant nurseries and in the reintroduced population.

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INTRODUCTION

Panicum fauriei var. *carteri* (Hosaka) Davidse, or Carter's panicgrass, is short-lived annual low-tufted grass in the Poaceae (grass) family. This variety is within one of 12 Hawaiian species of the genus *Panicum*. These species occur in the coastal habitat around the islands of Oʻahu, Molokaʻi, and Maui.

Species Report Overview

This Species Report summarizes the biology and current status of *Panicum fauriei* var. *carteri* and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the USFWS's Endangered Species Program. As such, the Species Report will serve as a living document and biological foundation of other documents such as recovery plans, status in biological opinions, and 5-year reviews.

Regulatory History

Panicum fauriei var. *carteri* was listed as an endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 *et seq.*), as amended (ESA) (listed entity was *Panicum carteri*) on October 12, 1983 (48 FR 46,328; USFWS 1983, p. 46,328). On May 23, 1994, the USFWS published a recovery plan (USFWS 1994, entire). On August 29, 2011, the USFWS finalized the 5-year status review of *Panicum fauriei* var. *carteri* and published an updated review on October 23, 2018 (USFWS 2011, 2018, entire).

Critical habitat was designated in a single unit consisting of the entire islet of Mokoliʻi (Chinaman's Hat) on the island of Oʻahu, totaling about 13 acres (5 hectares) (48 FR 46,328; USFWS 1983, p. 46,328). This designation includes habitat on City and County of Honolulu lands (Starr and Starr 2006, p. 49).

Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government and academic reports), and expert elicitation.

To assess the current status and viability of *Panicum fauriei* var. *carteri*, we identified population units. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a definite area over a span of evolutionary time, possesses an assemblage of genes (the gene pool) of its own, and has its own ecological niche. However, due to information gaps, we could not assess the viability of *Panicum fauriei* var. *carteri* using this definition. The Hawaiʻi and Pacific Plants Recovery Coordinating Committee (HPPRCC) revised its recovery objectives guidelines in 2011 and included a working definition of a population for plants: "a group of conspecific individuals that are in close spatial proximity to each other (i.e., less than 1,000 meters apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction" (HPPRCC 2011, p. 1).

Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 1,640 foot (ft) (500-meter [m]) buffer around each individual species point and polygon. We then dissolved all buffer areas intersecting each other into a single shape. Next, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. Finally, the Disperse Marker tool in ArcGIS Pro was used to shift the symbol markers that were overlapping so they would all be visible at the scale of the map. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

Species Viability

The Species Report assesses the ability of *Panicum fauriei* var. *carteri* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, (i.e., likelihood of avoiding extinction). To assess the viability of *Panicum fauriei* var. *carteri*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

Definitions

Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Panicum fauriei* var. *carteri.*

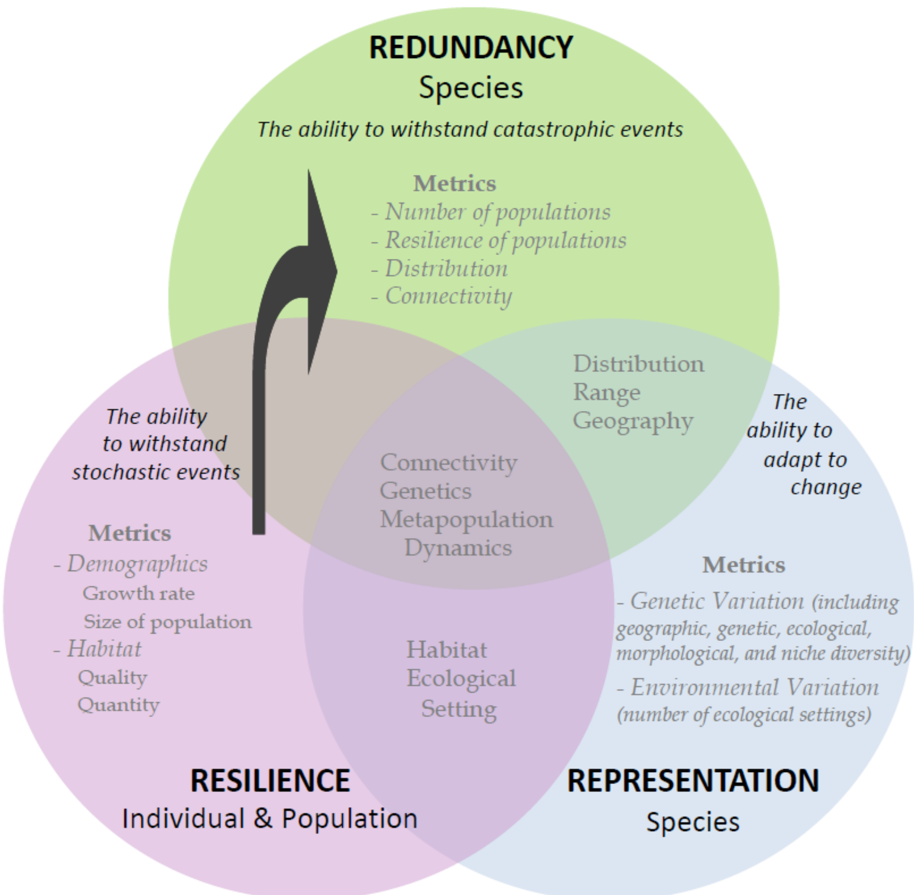

Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs”.

SPECIES ECOLOGY

Species Description

The genus *Panicum* consists of about 500 species occurring in warm and temperate regions of the world (Davidse 1999). Clark and Gould (1978) separated out the wet forest and bog plants that had been previously accepted as *Panicum* species by Hitchcock (1922, pp. 182–183) into the genus *Dichanthelium*. The affinities of the Hawaiian species of *Panicum* are obscure (Fosberg 1948). These endemic species differ from most other members of this genus in that all but one species exhibit the first glume as long as the spikelet (or nearly so) (Davidse 1999). In addition, the second floret of many of the Hawaiian species have the tendency to disarticulate from the rest of the spikelet when the fruit is mature while other Panicoid grasses tend to disarticulate below the glumes. The native Hawaiian species also have uncommonly variable apices of the glume, even within the same inflorescence. This accounts for the wide range of spikelet length in the descriptions.

Hawaiian *Panicum* consists of eighteen naturalized and endemic species (Davidse 1999, pp. 1,566–1,574). A revision of the Hawaiian species of *Panicum* merged eleven previously described species into the *Panicum fauriei* complex based on the uniform stem, leaf, and inflorescence morphology (Davidse 1990). The aerial stems are usually branched and puberulent (minutely pubescent, or bearing hairs; provided with fine, short, usually curled hairs). The leaves are attached to the stem above the ground. The blades are 0.6 to 4.78 in (1.5 to 12 centimeters [cm]) long and 0.04 to 0.16 in (0.1 to 0.4 cm) wide, loosely involute (margins rolled over the adaxial surface), upper surface pilosa (long hairs), lower surface puberulent (short hairs). The spikelets (cluster of flowers in the grasses) are arranged in a tightly branched inflorescence which is 0.4 to 4.3 in (1 to 11 cm) long. The axis and branches of the inflorescence are puberulent to sparsely pilose (short to longer hairs). This complex consists of three varieties (*P. fauriei* var. *carteri*, *P. fauriei* var. *fauriei*, and *P. fauriei* var. *latius*) that is based on spikelet morphology, particularly the length of glumes (bracts that subtend each spikelet in the grasses) and pubescence (hairs). The spikelets in *P. fauriei* var. *carteri* are 0.07 to 0.09 in (1.8 to 2.3 mm) long, acute, and shortly pubescent. Spikelets in *P. fauriei* var. *fauriei* are 0.06 to 0.09 in (1.5 to 2.3 mm) long, usually acute and glabrous (without hairs or glands). *P. fauriei* var. *latius* spikelets are 0.08 to 1.68 in (2 to 4.2 mm) long, acuminate (gradually and concavely tapering to a narrow, sharp point) to acute (sharp-pointed with straight or somewhat convex at the tip), shortpubescent with short to long tufts of hair at the apex of the glumes (Davidse 1999, p. 1,568; 1990b, p. 588). *Panicum carteri* Hosaka, *P. annuale* St. John, *P. kukaiwaaense* St. John, and *P. malikoense* St. John, were also placed in synonymy under *P. fauriei* var. *carteri* (Hosaka) Davidse.

The *Panicum fauriei* complex is a distinctive coastal species characterized by an annual habit (Davidse 1990, p. 588). In some habitats, Warshauer et al. (2009, p. 6) described *P. fauriei* var. *carteri* as appearing perennial and *P. f. fauriei* and *P. f. latius* as annuals. All are caespitose plants (tufted or turf-like plants) of mesic to dry, open, and disturbed sites. Differences between varieties are often misidentified in the field (Warshauer et al. 2009, p. 6; Oppenheimer pers. comm. 2020).

Individual Needs

The life cycle of *Panicum fauriei* var. *carteri* is based on what is known about the species. It is a short lived species, and is estimated that some individuals only live for a couple years, and others behave more like an annual, living only for one year (Oppenheimer pers. comm. 2020). The life stages (seed, seedlings, vegetative, and flowering plants) of *P. fauriei* var. *carteri* require very similar resources. Plants may die back during the drier summer to fall months in order to survive a period of drought. Seeds can also survive the period of drought (Bustamente pers. comm. 2020; Oppenheimer pers. comm. 2020). At the seed stage, the seeds are separated from the mother plant, and the seeds deposited onto soil or the following substrates: rock land, rough mountainous land, or Koʻele-Rocky complex soils (USFWS 2020, unpublished data). The seeds typically receive less than 47 in (1,200 mm) of average annual rainfall to germinate (USFWS

2020, unpublished data). Exposure to direct sunlight and sea spray are likely also key habitat characteristics for the species (USFWS 1983, p. 46,332).

Competition with other species (including native plants) or nonnative invasive species or both, can limit seedlings, vegetative plants, and flowering plants from getting water, soil, and sunlight that they need. Vegetative and flowering plants likely need the same important resources such as less than 47 in (1,200 mm) of average annual rainfall during the spring and summer months and exposure to strong sunlight and sea spray. Soil substrates noted above are required for vegetative and flowering plants. If all of the resource needs described above are met for a *Panicum fauriei* var. *carteri* individual, than the species may be highly resilient.

Little is known about the reproductive biology and nature of mortality of each life stage in *Panicum fauriei* var. *carteri* (USFWS 1983, p. 46,332; USFWS 1994, p. 10). It is not known whether outbreeding, inbreeding, apomixis (asexual reproduction without fertilization), or other sexual reproduction occurs (USFWS 1994, p. 10). However, if sexual reproduction is a reproductive strategy for *P. fauriei* var. *cateri*, the general process is likely similar to other members in the Poaceae family. *Panicum* flowers in the grass family are typically wind-pollinated; and composed of three stamens, two stigmas, and a single-chambered ovary (Stanley 1999, p. 5; Grant 1949, p. 85). Similarly, the Hawaiian *Panicum* genus is described by Davidse (1999, p. 1565) with three stamens and two styles (stalk that connects the stigma to the ovary). Wind pollinated plants evolved to have flowers reduced in size or completely absent (Mauseth 1988 as cited in Stanley 1999, p. 6). Reduced flowers result in small targets for wind-borne pollen; and while pollen is capable of being carried long distances by the wind, among angiosperms grass pollen is the shortest-lived pollen (Clayton and Renvoize 1986 as cited in Stanley 1999, p. 6). Effective pollination, therefore, occurs in a range of a few tens of meters under most circumstances (Clayton and Revoize as cited in Stanley 1999, p. 6). Further, Clayton and Renvoize (as cited in Stanley 1999, p. 6) reported that when grasses do flower they are only open for 2 to 3 hours to minimize the introduction of pathogenic fungal spores during anthesis (period during which a flower is fully expanded and functional).

Based on one herbarium report *Panicum fauriei* var. *carteri* was noted in flower and fruit during the month of February (Bishop Museum 2002). Two herbarium reports noted *P. fauriei* var. *carteri* in flower during the months of February and late August (Bishop Museum 1984; 2002). It is not known if flowers are present on plants at other times of the year. Plants were observed during the winter, spring, summer, and rarely in late fall (PEPP 2019; HBMP 2010; OANRP 2019).

Because *Panicum fauriei* var. *carteri* likely lives for one to three years, successive generations are reliant on yearly seed production (USFWS 1994, p. 10). Seed dispersal mechanisms for *P. fauriei* var. *carteri* is unknown, but based on other *Panicum* species, we assume the seeds are dispersed by wind, birds, and flowing water. Disturbance of the substrate can accelerate the erosion of topsoil, impacting the seedbank of *P. fauriei* var. *carteri* (USFWS 1994, p. 10).

Population Needs

To be resilient, a population needs to be healthy, which means it consists of abundant individuals within habitats that are adequate in area and quality. The population also needs to be stable or increasing in population growth and able to maintain survival and reproduction in spite of disturbance, including annual fluctuations in rainfall and seasonal fluctuations in rainfall and temperature. As mentioned above in **Individual Needs**, population sizes of *Panicum fauriei* var. *carteri* have been observed to fluctuate depending on how much rainfall has occurred (where there are typically more individuals observed after larger amounts of rainfall) and the time of year (where more individuals are typically observed furing the winter and spring months) (Bustamente pers. comm. 2020; Oppenheimer pers. comm. 2020). The known distribution of *P. fauriei* var. *carteri* consists of eight populations that contain mostly mature individuals. The population structure is not stable and the number of individuals has declined in all populations. Resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events. We define resiliency for *P. fauriei* var. *carteri* based on the metrics of population size (number of individuals), population growth rate and trends (over time), population structure (age or size class distribution: presence of seedlings, immature, and mature individuals).

Resilient populations of *Panicum fauriei* var. *carteri* need enough space, suitable habitat, and connectivity between populations to persist and survive over many generations. Maintaining connectivity between and among populations may be important in preserving existing genetic diversity for this species. Sufficient suitable habitat for populations of *P. fauriei* var. *carteri* occur in the coastal habitat as described in the Habitat Conditions section. The habitat is decreasing in size and quality due to the many threats influencing these areas. Therefore, sufficient suitable habitat and space is needed for *P. fauriei* var. *carteri* to facilitate recruitment and replacement of individuals to prevent populations from blinking out because of stochastic events. To evaluate population size, population growth rate and trends over time, and population structure, we will review the current and historic population data for *P. fauriei* var. *carteri*.

Species Needs

Redundancy is defined as the ability of a species to withstand catastrophic events. We define redundancy for *Panicum fauriei* var. *carteri* based on the metrics of the number of populations and the distribution and proximity of populations across its range. A species needs multiple resilient populations distributed across the landscape to be redundant.

Populations of *Panicum fauriei* var. *carteri* occur within a single habitat type located in the coastal ecosystem on the island of O‘ahu, Moloka‘i, and Maui. The historic and current population units are separated into three geographic regions, one located on islets off of windward O‘ahu; another located on the island of Moloka‘i; and two located on the island of Maui, one area each on West and East Maui. The population units on the island of O‘ahu are separated from each other by approximately 3 miles (mi) (4.83 kilometers [km]). Within the Maui regions, two populations are geographically located on the western side and two on the eastern side of the island. The western historic and current population units are separated from each other by approximately 1 mi (1.61 km); and the eastern historic and current population units are no more than approximately 4.5 mi (7.24 km) from each other.

Representation is defined by how unique traits are represented throughout populations across the range of the species. We will measure representation using these metrics, including the number of populations in a unique habitat type and the number of populations possessing unique traits. A species needs more than one population occupying the full range of habitat types used by the species to be represented.

No morphological, phenotypic, or molecular differences are known within and among populations of *Panicum fauriei* var. *carteri*. Botanists in the field generally have difficulty identifying this variety from the other species in the complex. Varieties are identified by the differences in the reproductive parts of the plant as described in Species Description section, making it very difficult to separate and accurately identify the species in the field.

There are known differences in elevation and average rainfall between the seven population units for *Panicum fauriei* var. *carteri*. Individuals are found at elevations between 46 to 263 feet (ft) (14 to 80 meters [m]) (USFWS 2020, unpublished data). The Makamakaʻole population unit is located near the top of the coastal habitat range at 984 ft (300 m) (Kim et al. 2020, p. 2). The lowest elevation is recorded at the Makawao-Olinda-B population unit at 46 ft (14 m) (USFWS 2020, unpublished data). The highest annual rainfall for all of the population units occurs on Molokaʻi and is over 79 in (2,000 mm) (Giambelluca et al. 2013). Six units had rainfall data available and five population units had data on elevation.

FACTORS INFLUENCING VIABILITY

A list of the factors influencing viability for *Panicum fauriei* var. *carteri* and associated conservation efforts implemented to reduce these factors are located in Table 1.

Threats

Nonnative Plants

Introduced invasive plants compete for resources; modifying the availability of light; altering soil-water regimes; modifying nutrient cycling processes; converting native-dominated plant communities to nonnative plant communities; altering fire characteristics of native ecosystems; leading to incursions of fire-tolerant nonnative plant species; and indirectly inhibiting the growth requirement of native species (e.g., allelopathy) (Smith 1985, pp. 180–181; Cuddihy and Stone 1990, p. 74; D'Antonio and Vitousek 1992, p. 73; Warshauer et al. 2009, p. 14). Introduced invasive plant species directly compete with and degrade habitat available for *Panicum fauriei* var. *carteri* (USFWS 2011, p. 11). The invasive plant species that are reported to have the greatest impacts to this species are *Bidens alba* var. *radiata* (beggartick), *Bidens pilosa* (beggartick), *Boerhavia coccinea* (red spiderling), *Casuarina equisetifolia* (ironwood), *Chloris barbata* (swollen fingergrass), *Conyza bonariensis* (hairy horseweed), *Cynodon dactylon* (Bermuda grass), *Dactyloctenium aegyptium* (beach wiregrass), *Desmodium* sp. (tick trefoil), *Digitaria ascendens* (Henry's crabgrass), *Digitaria ciliaris* (crabgrass), *Digitaria insularis* (sourgrass), *Emilia* sp. (Flora's paintbrush), *Indigofera suffruticosa* (indigo), *Lantana camara* (lantana), *Leucaena leucocephala* (haole koa), *Melinis repens* (natal redtop), *Nicotiana tabacum* (tobacco), *Opuntia ficus-indica* (prickly pear cactus), *Paspalum urvillei* (vasey grass), *Passiflora foetida* (love-in-a-mist), *P. suberosa* (corkystem passionflower), *Pluchea carolinensis* (sourbush), *P. indica* (marsh fleabane), *Portulaca oleracea* (pigweed), *Schinus terebinthifolius* (Christmasberry), *Sporobolus pyramidatus* (dropseed), *Stachytarpheta jamaicense* (Jamaica vervain), *Stenotaphrum secundatum* (buffalo grass), and *Terminalia catappa* (false kamani) (LeGrande 2002; USFWS 1994, p. 12; USFWS 2011, p. 10; Tangalin 2009; Wood 2008; 2010).

Introduced Ungulates

Introduced ungulates (cattle (*Bos taurus*); goats (*Capra hircus*); pigs (*Sus scrofa*); and axis deer (*Axis axis*)) directly graze, trample, and uproot plants as well as increase the erosion process which depletes the seedbank as topsoil washes into the ocean (USFWS 1994, pp. 5, 10; Wood 2010). Trampling by introduced ungulates may also compact the soil, disperse propagules of nonnative species, and increase the negative effects of nonnative plants as described above (USFWS 1994, p. 13; 2011, p. 10; Wood 2010). Goats, pigs, and axis deer often inhabit terrain that is often steep and remote and in locations where *Panicum fauriei* var. *carteri* occupy (Cuddihy and Stone 1990, p. 63; Wood 2010; USFWS 2011, p. 10; Warshauer et al. 2009, p. 15).

Rodents and Insects

Rats (*Rattus* spp.), mice (*Mus musculus*), and ants (unidentified species, Family Formicidae) are believed to consume the seeds and plant parts of *Panicum fauriei* var. *carteri* (USFWS 1994, p. 13; 2011, p. 11; Wood 2008; Bakutis pers. comm. 2020; Ching pers. comm. 2020). Rats are also known to eat the parts of other perennial native species that stabilize the soil where *P. fauriei* var. *carteri* occur (USFWS 1994, p. 13). Hawaiian plants are particularly susceptible to rat and mice predation because successful reproduction is reduced (Cuddihy and Stone 1990, p. 67; Kami 1966, pp. 367, 371). Given their impacts on native vegetation, rodents have the potential to significantly alter coastal communities (Kim et al. 2020, p. 11).

Fire or Other Catastrophic Events

Arson or accidental fire, hurricanes or tsunami, or flooding have the potential to destroy *Panicum fauriei* var. *carteri* (USFWS 1983, p. 46,328; 1994, p. 13). Fires destroy native habitats and create open areas for invasion by nonnative plants, this increases the negative effects caused by nonnative plants as described above (D'Antonio and Vitousek 1992, pp. 70, 73–74). Hurricanes exacerbate the impacts of other threats, by destroying native vegetation and creating disturbed areas conducive to invasion by invasive plants. Low elevation coastal areas where *P. fauriei* var. *carteri* occur may be destroyed if a tsunami overwashes the area and washes the seed bank away. Plants in low lying coastal areas can be inundated and these events can have devastating effects to native biota. Extreme flooding or flash flooding may occur and result in increased sedimentation, erosion, damage to plants, or eliminate one or more isolated occurrences of *P. fauriei* var. *carteri*. Because *P. fauriei* var. *carteri* persists in low numbers and in restricted ranges, natural disasters such as fires, hurricanes, tsunamis, or flooding are particularly devastating to this species and may result in the extirpation of remaining populations or extinction of the species.

Direct Human Disturbance

Threats to the survival of *Panicum fauriei* var. *carteri* also include trampling by humans and recreational biking (USFWS 1994, p. 12). Recreation users frequent areas occupied by the species and motorized dirt bikes or mountain bikes uproot plants (USFWS 1994, p. 12). At the time of listing, the unauthorized planting of coconut trees threatened the area in which *P. fauriei* var. *carteri* occupied (USFWS 1983, p. 46,330). Agriculture may have previously contributed to fragmentation of the habitat as well as by increasing the erosion of topsoil used by *P. fauriei* var. *carteri* (USFWS 1994, p. 12).

Low Number of Individuals
Panicum fauriei var. *carteri* faces the threat of low number of individuals (PEPP 2019). *P. fauriei* var. *carteri* may experience the following: (1) reduced reproductive vigor due to ineffective pollination or inbreeding depression; (2) reduced levels of genetic variability, leading to diminished capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence; and (3) increased likelihood that a single catastrophic event may result in extirpation of remaining populations and extinction of the species (Barrett and Kohn 1991, p. 4; Newman and Pilson 1997, p. 361; Pimm et al. 1988, p. 757; Mangel and Tier 1994, p. 607).

Lack of Regeneration
Depressed or loss of regeneration (reproduction and recruitment) in the wild has been observed, and is a threat to *Panicum fauriei var. carteri* (HBMP 2010; PEPP 2019). This lack of reproduction and recruitment is not well understood.

Climate Change
Changes in environmental conditions that may result from global climate change include increasing temperatures, decreasing precipitation, and increasing storm intensities (Intergovernmental Panel on Climate Change (IPCC) 2014, pp. 6–11). The consequent impacts on *Panicum fauriei* var. *carteri* are related to changes in microclimatic conditions in the species habitat. These changes may lead to the loss of native species associated in this species habitat due to direct physiological stress, the loss or alteration of habitat, or changes in disturbance regimes (e.g., droughts, fire, storms, and hurricanes). Because the specific and cumulative effects of climate change on *P. fauriei* var. *carteri* are presently unknown, we are not able to determine the magnitude of this possible threat with confidence.

Fortini et al. (2013, entire) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawai‘i using high resolution climate change projections. Climate change vulnerability is defined as the relative inability of a species to display the possible responses necessary for persistence under climate change. This assessment concluded that (at the species level) *Panicum fauriei* is vulnerable to the impacts of climate change with a vulnerability score of 0.435 (on a scale of 0 being not vulnerable to 1 being extremely vulnerable to climate change) (Fortini et al. 2013, p 83).

Increased inter-annual variability of ambient temperature, precipitation, and hurricanes, would provide additional stresses on the habitat and to this species as we expect climate change to exacerbate existing threats such as drought, fire, and invasive species. The probability of this species to go extinct as a result of such factors increases when its range is restricted, habitat decreases, and population numbers decline (IPCC 2014, pp. 6–11). Currently, *Panicum fauriei* var. *carteri* has limited environmental tolerances and ranges. Therefore, we expect this species will be vulnerable to projected environmental impacts that may result from changes in climate and subsequent impacts to its habitat.

Inadequate Regulatory Mechanisms
Inadequate Habitat Protection: Nonnative feral ungulates pose a threat to *Panicum fauriei* var. *carteri* through destruction and degradation of the species' habitat and herbivory but regulatory

mechanisms are inadequate to address this threat (USFWS 1981, p. 9,977). The State of Hawaiʻi provides game mammal (feral pigs and goats, axis deer, and mouflon sheep) management including hunting opportunities on 7 State-designated public hunting units on Oʻahu, 5 units on Molokaʻi, and 6 units on Maui (HDLNR 2015, pp. 15–19). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas (e.g., Game Animal Management Areas) to removal by State staff, or their designees, in other areas (e.g., Natural Area Reserves, some Forest Reserves, and some State Parks lands) (State of Hawaiʻi, H.A.R. 13-123).

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawaiʻi (USFWS 2013, pp. 64,679–64,682). The Hawaiʻi Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawaiʻi, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations. The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities (HDOA 2009, p. 1). The USFWS inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 et seq.), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. Under the Hawaiʻi Administrative Rules Chapter 4–70, the State of Hawaiʻi provides restrictions and exceptions for the importation of plant taxa. It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities such as commercial horticulture, goods and materials transportation, and agriculture. Many invasive weeds established on Hawaiʻi have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2013, pp. 64,679–64,682).

Conservation Actions

One population unit of *Panicum fauriei* var. *carteri* occurs on Kūkaʻiwaʻa Peninsula, part of Kalaupapa National Historical Park (KNHP) on Molokaʻi. The area where *P. fauriei* var. *carteri* occurs is regularly weeded to remove invasive nonnative plants (USFWS 2011, p. 12; 2018, p. 2). Since ungulate exclusion fencing (described below) was constructed in the area, the KNHP staff noted a remarkable increase in native species diversity, richness, and abundance which will benefit *P. fauriei* var. *carteri* (USFWS 2018, p. 2). Surveys conducted in 2007, documented invasive nonnative plants dominating the islets of Mokeʻehia and Mokoliʻi (Eijzenga and Preston 2008, pp. 25, 78). Many nonnatives also occur on Kapapa islet, but the dominant ground cover consists of native species (Eijzenga and Preston 2008, p. 38). DOFAW does not apply any efforts to managing non-native or native plants species at Mokoliʻi and Kapapa islets off of Oʻahu (Misaki pers. comm. 2020). Mokeʻehia islet off of Maui is managed as a State of Hawaiʻi Seabird Sanctuary; however, it is unknown if management is occurring to limit and reduce the spread of invasive nonnative plants.

Three of the four extant population units that contain individuals of *Panicum fauriei* var. *carteri* are not fenced, and thus, unprotected from the impacts of nonnative ungulates. The Moloka‘i population unit is the only one that is fenced and is protected from grazing and trampling by pigs and goats but not from axis deer (USFWS 2018, p. 2; Bakutis pers. comm. 2020). Two of these four extant population units are located on offshore islets off island of O‘ahu and Maui and are not exposed to the threat of ungulates.

Mokoli‘i islet is owned by the City and County of Honolulu and open to the public (Eijzenga and Preston 2008, p. 24). In 2002, the State of Hawai‘i, Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) and a group of community volunteers eradicated rats from Mokoli‘i Islet off to protect nesting wedge-tailed shearwaters (*Ardenna pacifica*) (USFWS 2011, p. 12). DOFAW continues to assist in managing the native wildlife but it is unknown what the current rodent status is there; however, with a stable wedge-tailed shearwater population DOFAW believes the island is rodent free (Misaki pers. comm. 2020). There have been no reports of rodents being observed on Kapapa and DOFAW has not found any evidence of rodents inhabiting the island (Misaki pers. comm. 2020). Additionally, in the spring of 2019, the State of Hawai‘i’s Plant Extinction Prevention Program (PEPP) reintroduced *Panicum fauriei* var. *carteri* to Kapapa islet off of O‘ahu; therefore, population monitoring will help to assess if there are any impacts from rodents. Ant control or eradication efforts have not been reported from any of the population units.

One population unit of *Panicum fauriei* var. *carteri* occurs in an area at a relatively low level of threat from fire due to its inaccessibility to people, humid climate, and low-growing vegetation (USFWS 2011, p. 12). An Environmental Assessment for the KNHP includes a plan to manage the threats from fire (NPS 2018, entire).

Attempts to germinate seeds of *Panicum fauriei* var. *carteri* were attempted in 1979, 1984, the early 1900s, and 2015, but were unsuccessful (Lyon Arboretum 2019; Tangalin 2009; USFWS 1994, p. 14; 2011, p. 12). However, seeds have been collected and successfully germinated at the Lyon Arboretum Seed Conservation Laboratory. Collections of *P. fauriei* var. *carteri* seeds from Kūka‘iwa‘a and Makawao-Olinda-B (87 and 2,641 seeds, respectively) are currently in storage at Lyon Arboretum. Seeds that have been stored have had a higher percentage of germination compared to fresh seeds, suggesting the possibly presence of physiological dormancy in the seeds (Lyon Arboretum 2020).

We define translocations as augmentations into existing populations, reintroductions into historic range where the wild population is extirpated, and introductions outside of historic range (following the IUCN Guidelines for Reintroductions and Other Conservation Translocations, 2013, entire). The PEPP reintroduced the first individuals of *Panicum fauriei* var. *carteri* on Kapapa Islet in 2019 (PEPP 2019; Ching pers. comm. 2020). The outplants were derived from stored seeds that were mostly stored when collected immature from the Makawao-Olinda-B population unit (Ching pers. comm. 2020; Oppenheimer pers. comm. 2020). The status of the outplants are currently unavailable due to access issues of the islet (Ching pers. comm. 2020).

PEPP, administered through the University of Hawaiʻi and State of Hawaiʻi, supports the conservation of plant species by securing seeds or cuttings (with permission from the State, Federal, or private landowners) from the rarest and most critically endangered native species for propagation and translocation (*http://pepphi.org*). PEPP focuses on species that have fewer than 50 plants remaining in the wild, while also prioritizing actions for species with 50–100 individuals remaining in the wild, or fewer than 50 individuals remaining on a particular islands, as time permits. Funding for this program is from the State of Hawaiʻi, Federal agencies (e.g., USFWS), and public and private grants. PEPP conducts these activities for *Panicum fauriei* var. *carteri*: collect, monitor, survey, and translocate. In 2012, PEPP reported that surveying or monitoring for this variety will increase to twice a year on Mokoliʻi; however, since that time it has been determined that the Oʻahu population may be extirpated (PEPP 2012). PEPP status of the Mokoliʻi population is now “ROI” (rare on island) (PEPP 2015). Occurrences on Molokaʻi are monitored by KNHP staff and PEPP (NPS 2015; PEPP 2015; Bakutis pers. comm. 2020). In May 2020, PEPP located approximately 20 individuals of *P. fauriei* at a new locations, Anahaki, Molokaʻi, but it is unsure if the variety for this population is *P. fauriei* var. *carteri* (Bakutis pers. comm. 2020).

Additional large-scale habitat level conservation actions are included under partnerships and landowner efforts. The East Molokaʻi Watershed Partnership (EMoWP), created in 1991, involving 7 partners and 5 associate partners, participate together to protect over 1,000 acres of native rainforest and primary water sources on the island in perpetuity (East Molokaʻi Watershed Partnership 2020, in litt.). The Kūkaʻiwaʻa population unit occurs within the area that the EMoWP works to protect (USFWS 2020, unpublished data). DOFAW manages the Mokeʻehia and Kapapa Islest as State Seabird Sanctuaries and permission to land must be obtained in writing from the DLNR. Vegetation monitoring occurs on a regular basis on all offshore islets; and rare species outplant monitoring occurs on an annual basis in coordination with the DOFAW, Oʻahu branch botanist (Misaki pers. comm. 2020). Management actions to control invasive plant species are ongoing by DOFAW wildlife staff (Misaki pers. comm. 2020). These actions include the removal of non-native vegetation as well as outplanting of common and rare native plant species outside the seabird nesting season (Misaki pers comm. 2020). The benefits of habitat restoration and conservation actions to protect native wildlife also provide a benefit to protect *Panicum fauriei* var. *carteri* on the Kapapa islet. It is not known if similar habitat restoration or conservation actions are occurring at Mokeʻehia to protect *P. fauriei* var. *carteri* in that population unit.

The Hawaiʻi Invasive Species Council (HISC) was established for the purpose of providing policy level direction, coordination, and planning among State departments, federal agencies, and international and local initiatives e prevention and control of invasive species. The Oʻahu Island Invasive Species Council (OISC) and Maui Invasive Species Council (MISC) concentrates control efforts on invasive plant species that pose the highest threat to ecosystems and quality of life on Oʻahu and Maui, respectively. Currently OISC concentrates its efforts on the following target pests: cane Tibouchina (*Tibouchina herbacea*), cape ivy (*Delairea odorata*), devil weed (*Chromolaena odorata*), fireweed (*Senecio madagascariensis*), glory bush (*Tibouchina urvilleana*), Himalayan blackberry (*Rubus discolor*; syn: *R. armeniacus*), miconia (*Miconia calvescens*), pampas grass (*Cortaderia jubata*, *C. selloana*), coconut rhinoceros beetle (*Oryctes rhinoceros*), coqui frog (*Eleutherodactylus coqui*), little fire ant (*Wasmannia* *auropunctata*), naio thrips (*Klambothrips myopori*), and rapid ʻōhia death (*Ceratocystis huliohia*, *C. lukuohia*) (https://www.oahuisc.org/target-pests/). MISC is currently targeting the following pests: miconia, blessed milk thistle (*Silybum marianum*), pampas grass, mullein (*Verbascum thapsus*), ivy gourd (*Coccinia grandis*), fountain grass (*Pennisetum setaceum*), little fire ant, coqui frog, and rapid ʻōhia death (https://mauiinvasive.org/misc-target-pests/). Some of these species have the potential to become established in habitat where they are found that are also areas for potential translocation of *Panicum faurieri* var. *carteri*.

The USFWS in 1983, determined endangered status under the ESA, as amended, *Panicum fauriei* var. *carteri* (USFWS 1983, entire). The primary purpose of the ESA is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the ESA. Conservation measures provided to species listed as endangered or threatened under the ESA include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The ESA encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The ESA and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the ESA prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the USFWS and State conservation agencies. The USFWS may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the ESA, is prohibited.

Damaging or destroying any of the listed plants in addition is violation of the Hawaiʻi State law prohibiting the take of listed species. The State of Hawaiʻi's endangered species law (HRS, Section 195-D) is automatically invoked when a species is federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. *Panicum fauriei* var. *carteri* occurs on non-Federal lands.

Table 1. The factors influencing viability and associated conservation actions listed by population for *Panicum fauriei* var. *carteri*. The Kapapa Islet population is a translocation; all other locations are wild.

Threats & Conservation Actions	***Hawaiian Island***	**Maui**	**Maui**	**Maui**	**Maui**	**Moloka‘i**	**O‘ahu**	**O‘ahu**
	Population Unit Name	Makawao-Olinda-A	Makawao-Olinda-B	Makamaka‘ole	Hauke‘e & Moke‘ehia Islet	Kūka‘iwa‘a Peninsula	Mokoli‘i Islet	Kapapa Islet
	Threat Nonnative Plants	Y	Y	Y	Y	Y	Y	Y
	Conservation Action Nonnative Plants	Unk	Unk	Unk	N	Y, removal of invasive nonnative plants	N	Y, some management
	Threat Introduced Ungulates	Y	Y	Y	Unk & N	Y	N	N
	Conservation Action Introduced Ungulates	N	N	N	N	Y, from pigs and goats but not axis deer	N	N
	Threat Rodents and Insects	Y	Y	Y	Y & Unk	Y	Y	Unk
	Conservation Action Rodents and Insects	Unk	Unk	Unk	Unk	N	Unk	Unk
	Threat Fire or Catastrophic Events	Y	Y	Y	Y	Y	Y	Y
	Conservation Action Fire or Catastrophic Events	N	N	N	N	Y, fire management plan for suppression response and fuel reduction practices	N	N

Y = yes; N = no; Unk = unknown

Table 1. The factors influencing viability and associated conservation actions listed by population for *Panicum fauriei* var. *carteri*. (continued).

	Hawaiian Island	**Maui**	**Maui**	**Maui**	**Maui**	**Moloka‘i**	**O‘ahu**	**O‘ahu**
Threats & Conservation Actions	*Population Unit Name*	Makawao-Olinda-A	Makawao-Olinda-B	Makamaka‘ole	Hauke‘e & Moke‘ehia Islet	Kūka‘iwa‘a Peninsula	Mokoli‘i Islet	Kapapa Islet
	Threat Direct Human Disturbance	Unk	Unk	Unk	N	N	Y	Y
	Conservation Action Direct Human Disturbance	Unk	Unk	Unk	Y, managed as a State Seabird Sanctuary	Unk	Y, posted signs to minimize disturbance	Unk
	Threat Low Number of Individuals	Y	Y	Y	Y	Y	Y	Y
	Conservation Action Low Number of Individuals	N	Y, seed collection	N	Y, monitoring	Y, seed collection, monitoring	Y, seed collection	Y, reintroduction, monitoring
	Threat Lack of Regeneration	Y	Y	Y	Y	Y	Y	Unk
	Conservation Action Lack of Regeneration	N	N	N	Y, monitoring	Y, monitoring	N	Y, monitoring
	Threat Climate Change	Y	Y	Y	Y	Y	Y	Y
	Conservation Action Climate Change	N	N	N	N	N	N	N
	Threat Inadequate Regulatory Mechanisms	Y	Y	Y	Y	Y	Y	Y
	Conservation Action Inadequate Regulatory Mechanisms	N	N	N	N	N	N	N

Y = yes; N = no; Unk = unknown

CURRENT CONDITION

Historical Condition

Pre-human Habitat Distribution and Description

All historic and current populations of *Panicum fauriei* var. *carteri* are located within the coastal dry communities; therefore, we will be referencing the Habitat Status Assessment for Hawaiian Islands coastal ecosystems (Kim et al. 2020, entire) to describe the habitat needs for this species. Associated native plant species may include *Argemone glauca* (pua kala), *Artemisia australis* (ʻāhinahina), *Bacopa monnieri* (ʻaeʻae), *Boerhavia repens* (alena), *Bidens hillebrandiana* subsp. *polycephala* (koʻokoʻolau), *Capparis sandwichiana* (maiapilo), *Centaurium sebaeoides* (ʻāwiwi), *Chenopodium oahuense* (ʻāweoweo), *Cyperus javanicus* (ʻahuʻawa), *Eragrostis variabilis* (kāwelu), *Euphorbia degeneri* (ʻakoko), *Fimbristylis cymosa* subsp. *umbellato-capitata* (mauʻu ʻakiʻaki), *Gossypium tomentosum* (maʻo), *Heliotropium anomalum* var. *argenteum* (hinahina), *H. curassavicum* (kīpūkai), *Heteropogon contortus* (pili), *Ipomoea pes-caprae* subsp. b*rasiliensis* (pōhuehue), *Jaquemontia ovalifolia* subsp. *sandwicense* (pāʻū o hiʻiaka), *Lepidium bidentatum* var. *o-waihiense* (ʻānaunau), *Lipochaeta integrifolia* (nehe), *Lepturus repens*, *Lycium sandwicense* (ʻōhelo kai), *Lysimachia mauritiana*, *Myoporum sandwicense* (naio), *Nama sandwicensis* (hinahina kahakai), *Panicum torridum* (kākonakona), *Pittosporum halophilum* (hōʻawa), *Plumbago zeylanica* (ʻilieʻe), *Portulaca lutea* (ʻihi), *Psydrax odorata* (alaheʻe), (*Santalum ellipticum* (ʻiliahialoʻe), *Scaevola taccada* (naupaka kahakai), *Schiedea globosa*, *Sesuvium portulacastrum* (ʻākulikuli), *Sida fallax* (ʻilima), *Solanum americanum* (pōpolo), and *Sporobolus virginicus* (ʻakiʻaki), *Tephrosia purpurea* var. *purpurea* (ʻauhuhu), *Tetramolopium sylvae*, and *Waltheria indica* (ʻuhaloa) (Gagné and Cuddihy 1999, pp. 55–62; Wood 2008; 2010; Eijzenga and Preston 2008, pp. 25–30, 38–40, 78–79; Perlman 2010).

Based on what we know about *Panicum fauriei* var. *carteri* and its biology and life history needs, it is possible that before the arrival of humans to the Hawaiian Islands, *P. fauriei* var. *carteri* was more widely distributed throughout its range. The coastal habitat has experienced a great change and loss due to development pressure and habitat degradation, increasing habitat fragmentation and decreasing the amount and quality of habitat available for this species (Kim et al. 2020, p. 13).

Historic Trends of *Panicum fauriei* var. *carteri*

There is no historical documentation describing the former range of *Panicum fauriei* var. *carteri* (USFWS 1994, p. 6). Surveys and voucher specimens have documented *P. fauriei* var. *carteri* from the islands of Oʻahu, Molokaʻi, and Maui (USFWS 1994, pp. 4–6). Six populations were known: the islet of Mokoliʻi on the windward side of Oʻahu; on a sea headland west of Maliko Gulch, on East Maui; northeast of Maliko Gulch on a windward coastal cliff called Watercress Point, on East Maui; the south side of Makamakaʻole Stream on the east coast of Maui; at Wailena Gulch, west of Hakuheʻe Point, on sea cliffs in West Maui; on the islet of Mokeʻehia; and on Kūkaʻiwaʻa point on the north coast of East Molokaʻi (USFWS 1994, pp. 4–6). Plants were known to grow on sea cliffs and within the ocean spray zone at these locations (USFWS 2011, pp. 9–10).

In 1941, the population on Mokoliʻi Islet was comprised of only 12 individuals on a rocky ledge frequently drenched by sea spray (USFWS 1984, p. 5). Herbst observed a single disjunct population with two colonies (180 plants and 27 plants) about 49 ft (15 m) apart at the islet in the exceptionally wet year of 1978, 257 individuals were found (USFWS 1983; 1994, p. 5; Bishop Museum 1978a; 1978b). Because it was not recorded between 1941 and 1978, the species had been believed to be extinct, although no detailed records exist of attempts to relocate it in the intervening time period (USFWS 1983). In 1992, a group of 20 to 30 individuals were seen at that location (USFWS 2011, p. 8). In 2002, the population had about 25 individuals, but from 2002 to 2007 an invasive grass had spread into the area and no plants were found. In June 2008, four individuals were found in the same location, indicating the presence of a viable seedbank (Eijzenga and Preston 2008, p. 30; USFWS 2011, p. 8). In 2015, no individuals were found on the islet (PEPP 2017). The last observation of plants on the islet was reported in 2009 (PEPP 2019).

The Makawao-Olinda-A population near Maliko Gulch, in West Maui, was not seen since the middle 1980s and described as possibly extinct (HBMP 2010; USFWS 1994, p. 5). Sylva discovered two additional populations at Mokolea Point and Makawao-Olinda-B (Watercress Point); however, the population at Mokolea Point was not found again when surveyed for in the early 1980s and may have been originally misidentified as *Panicum fauriei* var. *latius* (USFWS 1994, p. 5; HBMP 2010; Oppenheimer pers. comm. 2020). In 1992, one vegetative plant of *P. fauriei* var. *carteri* was documented at Makawao-Olinda-B consisting of five clusters in an area of 4,303 ft^2 (400 m^2) at 66–133 ft (20–40 m) above sea level (HBMP 2010; USFWS 1994, p. 6, 9). In 1992, the population on West Maui at Makamakaʻole was observed, and consisted of three clusters of plants of (28, 29, and 44 individuals) in a 4,303 ft^2 (400 m^2) area at the base of a steep slope 10–33 ft (3–10 m) above sea level, near the Makamakaʻole river mouth (USFWS 1994, p. 6). A few individuals of *Panicum fauriei* var. *carteri* were observed in 1998, in West Maui in Wailena Gulch, west of Hakuheʻe Point, on sea cliffs at 50 ft (15 m) elevation (Wood 2010). Plants are also known from the islet of Mokeʻehia (Oppenheimer pers. comm. 2020).

A single specimen, collected in 1984, was deposited in the type collection at Bishop Museum from the sea cliff at Kūkaʻiwaʻa, Molokaʻi (USFWS 1994, p. 6). The population at Kūkaʻiwaʻa consisted of two disjunct subpopulations in 1992, and was separated by approximately 820–984 ft (250–300 m) (USFWS 1994, p. 9). A subpopulation of approximately 80 plants was distributed along 164 ft (50 m) of the west-facing perimeter of the peninsula while another 120 plants were clustered in the largest gulch to the east of the point (USFWS 1994, p. 10). Most of the 200 individuals were in flower or fruit (USFWS 1994, p. 9). A survey in 2002, documented 457 individuals with the greatest concentration of plants on the western side of the peninsula (LeGrande 2002; USFWS 2011, p. 8). A single population was located on the east side of the peninsula (LeGrande 2002; USFWS 2011, p. 8). While it was reported that the population was relatively stable in 2010 (Huges pers. comm. 2010), by 2015, estimates of the species dropped from 500 to fewer than 100 individuals (Warshauer et al. 2009; NPS 2015; PEPP 2015).

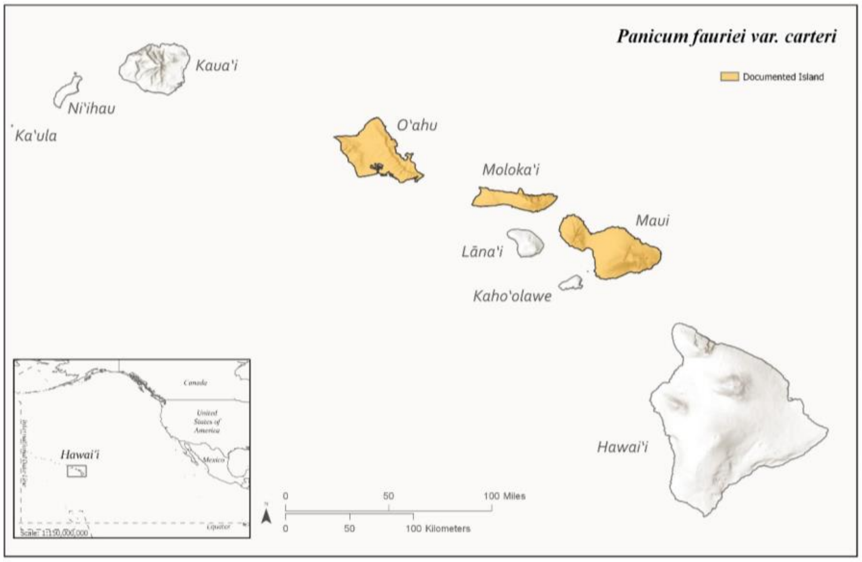

Figure 2. Range map for *Panicum fauriei* var. *carteri*.

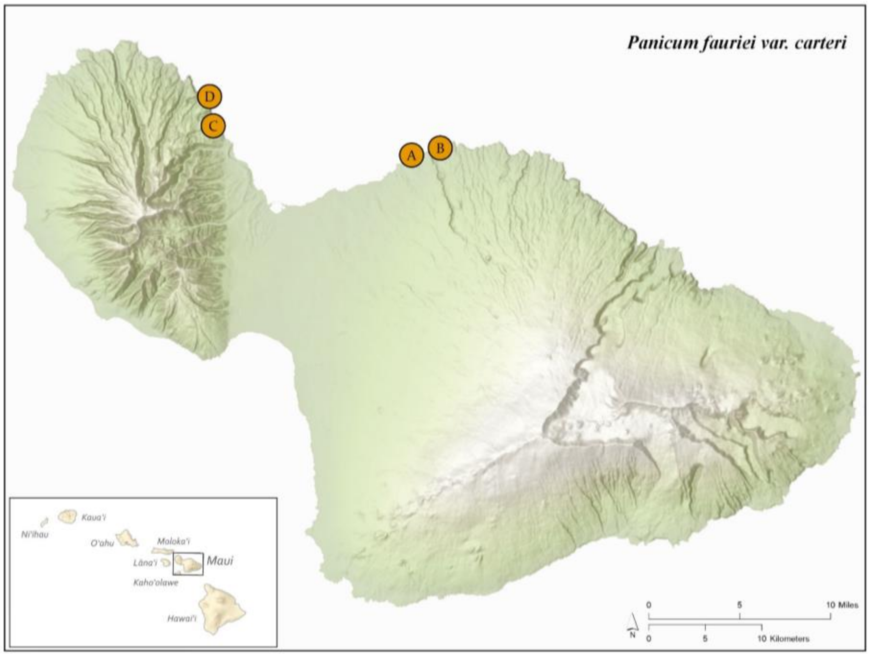

Figure 3. Distribution of *Panicum fauriei* var. *carteri* on the island of Maui. (**A** refers to Makawao-Olinda-A (current), **B** is Makawao-Olinda-B (current), **C** is Makamaka‘ole (current), **D** is Hauke‘e & Moke‘ehia (current); USFWS unpublished data).

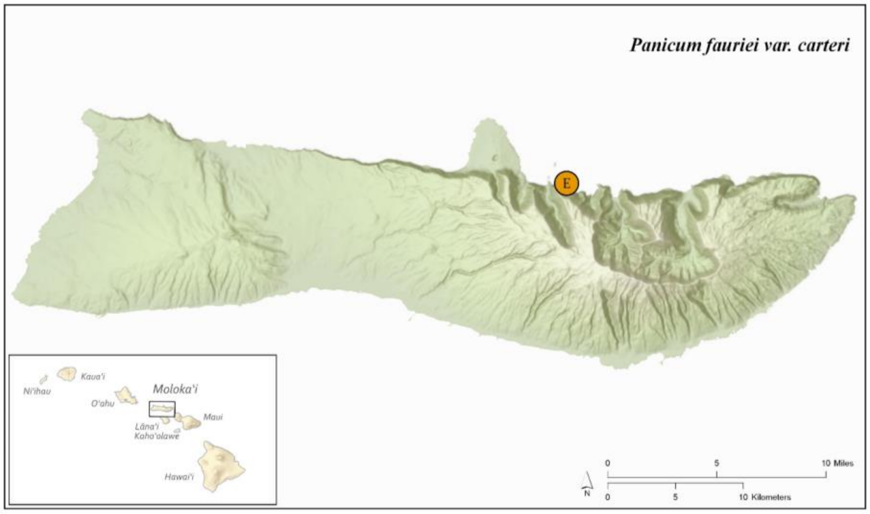

Figure 4. Distribution of *Panicum fauriei* var. *carteri* on the island of Moloka‘i. (**E** refers to Kūka‘iwa‘a (current); USFWS unpublished data).

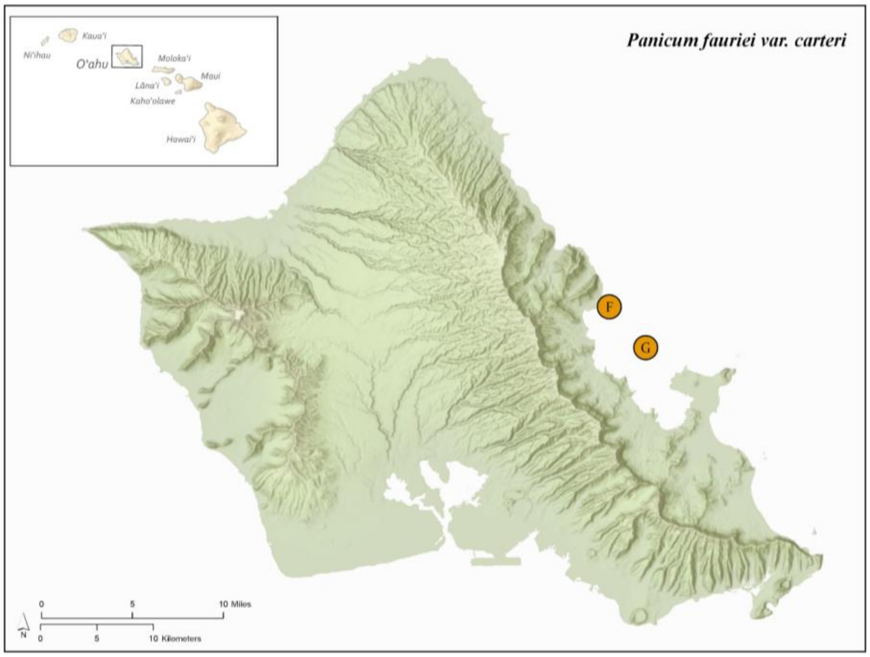

Figure 5. Distribution of *Panicum fauriei* var. *carteri* on the island of O‘ahu. (**F**, refers to Mokoli‘i Islet (current), **G** is Kapapa Islet (current and reintroduced); USFWS unpublished data).

Current Condition

When *Panicum fauriei* var. *carteri* was first listed, it was known from one occurrence totaling slightly over 200 individuals on the islet of Mokoli‘i (USFWS 1983, p. 46,328). Currently, this species is known to be extant at three wild population units (Makawao-Olinda-B and Kūka‘iwa‘a) and one reintroduced population unit (Kapapa Islet). These populations contain approximately 860–960 individuals across the four known population units (USFWS 2020, unpublished data). The Makawao-Olinda-A population unit was not observed since the middle 1980s (HBMP 2010; USFWS 1994, p. 5). The Makawao-Olinda-B population unit contained approximately 800–900 individuals in 2015; however, since then erosion of the steep slopes has covered many of the ledges that they were on and alien plants have replaced them (Bustamente pers. comm. 2020). Bustamente (pers. comm 2020) observed far fewer individuals in 2018 but only went to a small portion of the area they inhabit and noted that it was not the best time for observing the species. The population unit at Makamaka‘ole was last observed in 1992, with approximately 101 individuals and its current status is unknown (USFWS 2020, unpublished data). It has been documented that plants are within the Hauke‘e and Moke‘ehia population unit (Oppenheimer, pers. comm. 2020). However, the current status of individuals from these two locations in this population unit is unknown. Within the Kūka‘iwa‘a population unit, approximately 20 individuals were last observed (Bakutis pers. comm. 2020). This wild population is in decline as there were 200 to 457 individuals recorded from 1992 to 2002 (USFWS 1994, p. 9; 2011, p. 8; LeGrande 2002). In May of 2020, Bakutis (pers. comm. 2020) might have identified another small population of approximately 20 plants at Anahaki, but taxonomic confirmation of *P. fauriei* var. *carteri* has not yet been occurred. The Mokoliʻi Islet population unit has not been observed since 2009, and has continued to decline since the species was listed (USFWS 1983; 1994 p. 5). The Kapapa Islet population consists of 40 recently reintroduced plants but success of the outplants and recruitment has not yet been determined.

Table 2. Current and historic populations units of *Panicum fauriei* var. *carteri*

Hawaiian Island	**Population Unit Letter**	**Population Unit Name**	**Last Observation Date**	**Extant?[1]**	**Population Type**	**Population Trend[2]**	**Estimated Number of Sites**	**Estimated Number of Individuals**
Maui	A	Makawao-Olinda-A	Mid-1980	No	Wild	D	1	Unk
Maui	B	Makawao-Olinda-B	4/13/2015	Yes	Wild	D	1	800–900 plants
Maui	C	Makamaka‘ole	7/3/1992	Unk	Wild	D	1	101 plants (in 3 clusters of 28, 29, and 44
Maui	D	Hauke‘e & Moke‘ehia	Unk	Yes	Wild	Unk	2	Unk
Moloka‘i	E	Kūka‘iwa‘a Peninsula	2020	Yes	Wild	D	1	~20 individuals
O‘ahu	F	Mokoli‘i Islet	2009	No	Wild	D	1	0 individuals
O‘ahu	G	Kapapa Islet	3/14/2019	Yes	Reintroduction	N/A	1	40 mature

[1]Unk = unknown;
[2] D = decreasing; Unk = Unknown; N/A = not applicable
[3]estimates from 1992, not current

SPECIES VIABILITY SUMMARY

Resiliency

For *Panicum fauriei* var. *carteri* to maintain viability, the populations must be resilient, meaning they must have healthy, stable populations and able to maintain survival and reproduction in spite of disturbance. We determined resiliency for *P. fauriei* var. *carteri* based on the metrics of population size (number of individuals), population growth rate and trends (over time), and population structure (age or size class distribution: presence of seedlings, immature, and mature individuals). Populations are resilient if there are large numbers of populations with abundant individuals. Currently, there are 3 population units of *P. fauriei* var. *carteri* containing approximately 820–920 wild individuals and one population unit of 40 reintroduced individuals. Natural recruitment has been noted in the wild populations but not yet been observed in the reintroduced population. The number of individuals has declined over the years. Habitat degradation by feral ungulates and nonnative plants are continuing to occur. Rodents and insects, direct human disturbance, and lack of regeneration are the biggest threats to this species, and along with the species needs, largely results in the fluctuation of the number of individuals.

In summary, the resiliency of *Panicum fauriei* var. *carteri* within each population unit, along with a short description on the justification for each score, is provided in Table 3 below. The Makawao-Olinda-A and Mokoliʻi wild population units both have <u>no</u> resiliency, as there are no known wild individuals of *P. fauriei* var. *carteri* at either site, so the only resiliency that remains at these populations is represented in the possible presence of a persistent soil seed bank. The Kūkaʻiwaʻa population unit is analyzed as <u>low</u> because there are approximately only 20 wild individuals, the population has been declining over time, but the habitat is fenced, protecting it from some ungulates, and management to revoke the threat of nonnative plants is occurring. Additionally, it has not yet been confirmed that a second population of *P. fauriei* var. *carteri* exists at Anahaki. The resiliency of *P. fauriei* var. *carteri* at Makawao-Olinda-B is moderate because there are more individuals remaining; however, recent observations show a decrease in numbers of individuals. The resiliency of *P. fauriei* var. *carteri* at Makamakaʻole and Haukeʻe and Mokeʻehia is <u>low</u> and <u>very low</u>, respectively, because there are wild individuals remaining; but trends cannot be accurately analyzed due to lack of recent data. Lastly, the resiliency of the reintroduction at Kapapa Islet could not be determined as there has been no observations of this translocation after the initial outplanting. Overall, the resiliency of *P. fauriei* var. *carteri* is considered <u>very low to low</u> due to only one population having a moderately large population of approximately 800–900 plants as well as having some representation *ex situ*; but very low numbers and continued decline in population sizes for the other populations.

Table 3. Resiliency of populations of *Panicum fauriei* var. *carteri*.

Population Unit Letter	**Population Unit Name**	**Resiliency**	**Justification**
A	Makawao-Olinda-A	None	No known wild individuals
B	Makawao-Olinda-B	Moderate	800–900 wild individuals in 2015; *ex situ* representation
C	Makamakaʻole	Low	101 wild individuals in 1992
D	Haukeʻe / Mokeʻehia	Very Low	Unknown number of individuals
E	Kūkaʻiwaʻa Peninsula	Low	~20 wild individuals with natural recruitment and potentially a second population of ~20, but questionable taxonomic ID; *ex situ* representation
F	Mokoliʻi Islet	None	No known wild individuals
G	Kapapa Islet	None	Recent reintroduction; no data on success

Redundancy

We define redundancy for *Panicum fauriei* var. *carteri* based on the metrics of the number of resilient populations and the distribution and proximity of populations across its range. Currently, there are only four known population units for this species, including one recently reintroduced population. The narrow distribution of this species is confined to the dry coastal habitat on the islands of Oʻahu, Molokaʻi, and Maui. The range of *P. fauriei* var. *carteri* has decreased from what was known historically. Seven population units are historically known with four currently extant. Overall losses of habitat in the coastal areas this species will continue to preclude and further limit ability for redundancy in the current condition, especially as impacts of climate change, such as in increase in storm severity and frequency, as well as sea level rise, could continue to degrade the habitat and lead to catastropihic events, both of which can contribute to population extirpations. The extant individuals located within the Makawao-Olinda-B population unit are not in close proximity to other population units. The Makamakaʻole and the Haukeʻe and Mokeʻehia population units are located within close proximity of each other. With the extirpation of the wild Oʻahu population and uncertainty of the status of the Oʻahu reintroduction and West Maui populations, as well as the low resileincy of the Molokaʻi population, the evaluation of redundancy is <u>low</u> in the current condition.

Representation

Representation is defined by how unique traits are represented throughout populations across the range of the species. We will measure representation on the metrics of the number of populations, and their resileincy, in a unique habitat type and the number of populations possessing unique traits. A species needs more than one resilient population occupying the full range of habitat types used by the species to be represented. Using the best available scientific data, there is no environmental variation represented throughout the range of *Panicum fauriei* var. *carteri*. All population units of *P. fauriei* var. *carteri* are distributed within the coastal habitat type. No genetic studies have been done on this species. Morphological diversity has not been studied between populations of *P. fauriei* var. *carteri* and it does not occupy a range of elevations; however, we assume that there are unique traits in each region that the species occupies because of the geographic separation that historically and currently exists. On Maui, only the Makawao-Olinda-B population is currently represented *ex situ* and seeds were used for the reintroduction at Kapapa. The other East Maui population is not extant or represented *ex situ*. The status of the West Maui populations is currently not known and there have been no collections of seeds for storage. Therefore, only the Makawao-Olinda-B population has some amount of representation out of all the Maui populations. The one wild population on the island of Oʻahu is no longer extant and no collections had been secured in *ex situ* representation and is not represented elsewhere at reintroductions. Therefore, there is no representation of the Oʻahu population. The Molokaʻi population unit is currently persisting at a low number with little genetic storage. This population, being isolated on Molokaʻi and at a slightly higher average annual rainfall than the other populations, is lacking any *in situ* representation and has low resileincy. Overall, the evaluation of representation is very low to low.

Species Viability Summary
On the species level, *Panicum fauriei* var. *carteri* has very low to low resiliency, redundancy, and representation; therefore, the overall viability of this species is very low to low in the current condition (Table 4). Some redundancy and representation is maintained in *ex situ* rare plant nurseries and in the reintroduced population, but no reintroduced individuals resulting from these efforts have yet been documented to be naturally recruiting in the wild. In addition, not all threats are being sufficiently managed throughout the range of the species. Therefore, *P. fauriei* var. *carteri* is particularly vulnerable to stochastic or catastrophic events.

Table 4. Viability of current condition of *Panicum fauriei* var. *carteri*.

Species Name	**Overall Resiliency**	**Redundancy**	**Representation**	**Viability**
P. fauriei var. *carteri*	Very Low to Low	Low	Very Low to Low	Very Low to Low

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